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Wireless Sensor Network Based Irrigation Management System for Container Grown Crops in Pakistan

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Abstract: Irrigation procedures are based on farmer's experience, soil properties and environmental conditions that are affected by changes in environmental conditions. Wireless sensor network is a solution for monitoring environmental conditions and efficient utilization of water. In this paper, an effective irrigation management system is presented for the container grown crops. It utilizes wireless sensor network for obtaining soil properties and environmental data continuously. Irrigation schedule of different plants is planned according to their requirement which is based on the data obtained from sensor nodes deployed at different locations. The irrigation management system investigates data to identify water deficient locations and informs the farmers about it via alarming unit or a text message sent over LAN.

Key words: Wireless sensor networks · Environmental parameters · Container grown crops · Irrigation management system

INTRODUCTION

Agriculture is considered as a vital sector throughout the world but the ratio of modern technology and innovation acceptance is very hard. However, innovations having the potential to increase yield by utilizing less resources are accepted [1]. Activities in agriculture sector are carried out through traditional manual procedures that are time consuming and labor expensive [2]. During last decade, the paradigm is shifted towards technology and now innovations are accepted at commercial level in agriculture sector as well. It results in automations of different agriculture activities called precision farming or precision agriculture. It argues that crops quality and production rate is improved by providing right resources at right the time in presence of suitable environmental conditions. Different methods are adopted for collecting environmental and soil related information such as temperature, air humidity, wind direction, soil moisture and soil temperature etc [3].

Wireless sensor network consists of low cost, low powered and multifunctional sensor nodes capable of sensingits surrounding phenomenon and communicating wirelessly to a central location either directly or through multi hops. These characteristics motivated researcher to deploy wireless sensor networks in different applications such as military, agriculture, habitat monitoring, smart house and buildings, industry and medical etc [4,5]. Apart from a few developed countries, agriculture sector lacks technology because the cost associated with adoption of technology is high as compared to its yield. During last decade, reduction in the cost of technology especially in sensors and activators motivated researchers as well as investors to automate different agriculture activities using wireless sensor networks. Initial experiments were carried out in a controlled environment such as green houses and container crops etc [3].

Irrigation plays an important role in crops production. It is based on the farmer's experience, environmental conditions and soil properties but these procedures are labor expensive, time consuming and wastage of resources. Therefore, adaption of technology is necessary for efficient utilization and saving of fresh water. Every single drop of water is important for human beings and should be used efficiently. Wireless sensor network is a desirable solution for automating irrigation procedures, efficient utilizations of water and yield production etc [6]. During last two decades, wireless sensor networks are

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used extensively in different parts of agriculture sector ranging from irrigation management to pest and disease control.

The irrigation schedule of different crops varies depending on weather conditions, soil properties, crops requirements and availability of water and it ranges from 3 to 30 days [7]. But the irrigation schedule of container grown crops is quite different from that of open field's crops. It requires a regular irrigation schedule once or twice a day or it varies depending on the environmental conditions [8]. The traditional irrigation procedure is labor extensive and time consuming because it requires regular visits and attention. Therefore, wireless sensor network is a suitable candidate for the irrigation of container grown crops. Sensor nodes are deployed at different locations and send the desired information to a central location via gateway after a defined time intervals [9].

In response to the problem stated, in this study a wireless sensor network based irrigation management system (IMS) for the irrigation schedule of container's grown crops is presented. Sensor nodes are capable of sensing various parameters required for a desirable irrigation schedule such as temperature, air humidity and soil moisture. It sends it to a central location via gateway where IMS analyze it. The IMS informs farmers about locations where irrigation is needed. This is done via a text message sent on local area network (LAN) or through a short SMS or activating an alarming unit. The productivity of container grown crops is improved due to regular and need based irrigation schedule. It provides timely information about environment and soil properties and saves farmers time and efforts.

The article structure is as given: in section 2 a brief literature overview is given, section 3 explains the irrigation management system, section 4 contains the proposed design of irrigation management system, section 5 explains the experimental procedure and analysis of data coming from sensor nodes and in section 6 concluding remarks are given.

Wireless Sensor Networks in Agriculture: Advancement in technology leads to reduction in cost and size of sensor nodes [10]. It is used in various applications such as military, smart homes and offices, agriculture and environmental monitoring etc. Precision agriculture is an important application of wireless sensor network and various studies were carried out by researchers [1]. It is used for sensing different parameters such as temperature, air humidity, soil moisture, wind directions and leaf wetness etc [11].

In Lofar project, wireless sensor network is used for the prediction of phythophthora disease [12]. In vineyard monitoring system [13], it is used for disease prediction, pest controls, disease location information and helps managers in various activities. The quality of river basin water is observed by Kotamaki *et al*. [14] by deploying sensor nodes at different locations. The impact of Soil parameters over crops yield is investigated. In tomato disease prevention system, wireless sensor network is deployed for controlling environmental conditions inside green house and it prevents disease favorable conditions to occur [15]. Greenhouses automatic controlling with wireless sensor networks are also investigated in [16-18].

In Common-sense net project, the capabilities of wireless sensors network for marginal forming are investigated [19]. In order to conserve rainy water for long term usage, soil moisture sensors are used. Different types of sensors are used for controlling various diseases related to environment. Flow AID project team used wireless sensor network for controlling irrigation under certain conditions such as water deficiency [20]. Soil properties and environmental conditions are key factors for a suitable irrigation schedule. Therefore, different site specific automatic irrigation control systems based on sensor networks were investigated for enhancing crops yields and efficient utilization of water [21-24]. M. Dursun *et al*. [25] have proposed sensor based automatic irrigation management system. The irrigation schedule of cheery trees is managed efficiently through sensor nodes deployed at different places.

Irrigation schedule is an important task and need to be handled wisely and efficiently. The literature is quiet bulky in using wireless sensor networks for irrigation management but none of them is focusing on the actual issues efficient utilization. In this paper, an efficient irrigation scheduling mechanism is presented for the container grown crops. The water is provided on needed bases. It presents an irrigation scheduling mechanism for the farmers having fewer resources that can be followed during four different seasons. This schedule is based on the data obtained from wireless sensor networks deployed at the nursery of our institute.

Irrigation Management System: The proposed irrigation management system is used for controlling irrigation schedules of container grown crops. The irrigation schedule is based on temperature, air humidity and soil moisture values obtained from sensor nodes deployed at different locations inside nursery. The data is analyzed by irrigation management system for further actions. There are two basic units of it namely hardware unit and software unit.

Hardware Unit: In irrigation management system, wasp-mote agriculture sensor boards are used because they are specially designed for handling different agricultural activities. It is supporting up to 14 different sensors at the same time and switches to different operational modes for prolonging batteries lifetime. The schematic diagram of wasp-mote agriculture sensor board along with sensors is shown in Fig.1. There are two types of agriculture board simple and pro boards. A pro board has the capacity of connecting four extra nodes than a simple board. Each board is equipped with 3.7 volts lithium-ion battery having the capability of running sensor boards up to 6 months. The board supports solar panel up to 12 volts for charging batteries [26]. Figure 1 shows the diagram of wasp-mote agriculture pro board with different sensor connected to it. The board has AT mega 1281 microprocessor and 2 GB micro-sd card port. The soil moisture and leaf wetness sensor are pointed out by dotted arrow. For precise and accurate analysis of soil moisture the board supports three soil moisture sensors at the same time. Figure 2 shows the XBee-802.15.4 communication module to be integrated with wasp-mote agriculture boards. It communicates with microcontroller at baud rate of 38400 bps speed through UART_0. The transmission range of this module is about 500 meters. In Fig.2 SHT75 sensor is shown. It senses temperature and air humidity after a defined interval of time.

Gateway is an important part of wireless sensor networks and acts as a bridge between sensor nodes and server. A wasp-mote gateway is presented in Fig. 3. It communicates wirelessly with sensor nodes and through USB port with computer.

Software Unit: Sensor nodes send data after a defined interval of time to a central location via gateway. The serial monitor designed for wasp-mote receives data through USB port but does not allow copying or saving it. To solve this problem, Cool Term software [27] is used which stores data automatically. The irrigation management system running on PC reads every packet of data received through USB port and checks it for vulnerable condition. It investigates the soil moisture parameter along with temperature and humidity readings for the identification of water deficient locations.

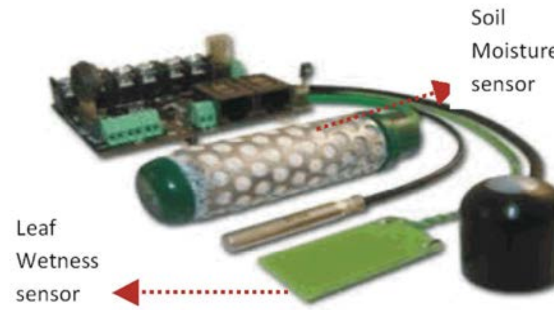

Fig. 1: Wasp-mote Agriculture Board [26]

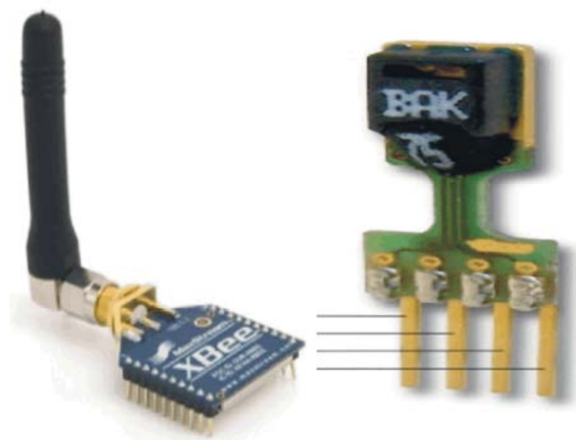

Fig. 2: Xbee module, Sensirion temperature & humidity sensor and Gateway [26]

Fig. 3: Wasp Mote Gateway [26]

It starts an alarm if the soil moisture value is below the minimum threshold value. In order to inform the farmer, alarming unit is needed to be activated and also an activation message must be sent via LAN.

Design of the Irrigation Management System: Automatic control of irrigation mechanism requires regular monitoring of different parameters 24 hours/7 days a week. For this purpose, wasp-mote agriculture boards

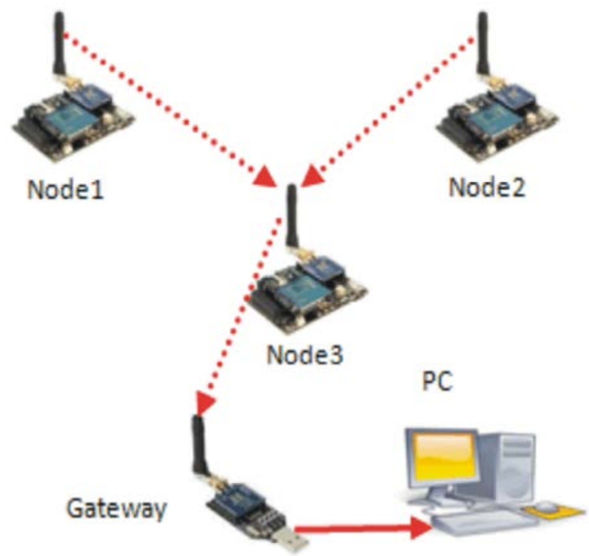

Fig. 4: WSN for irrigation management system

are deployed at three different locations inside nursery situated just outside our institute. In early stages of experimental setup, each node was communicating directly with gateway. But for covering more area, one of them is working as a relay node in addition to its own activities for other nodes because they are not within the specified communication range. The design of experimental setup is shown in Fig.4. The dotted arrows represent wireless communication where the solid arrow represents wired communication through a defined USB port. The gateway is connected through USB port in our experimental study. Each sensor node is capable of sensing temperature, air humidity and soil moisture. The wireless communication is in a range of about 500 meters. Node3 is deployed about 450 meters from the gateway and is able to communicate directly with it.

The other two nodes are deployed at a distance of about 400 meters from the Node3 as shown in Fig.4. The distance between nodes and gateway is kept low in order to reduce packet losses. Node1 and Node2 send their packets to Node3 because they are unable to communicate directly with gateway in our experimental setup. By investigating the destination address Node3 forward these packets to gateway without making any changes in it. The gateway acts as a bridge between sensor nodes and PC. The data is received in PC via a defined serial port that is COM6 in our case. The irrigation management system checks the received data for any vulnerable condition and inform farmer if the soil moisture parameter is below the defined frequency threshold value for it that is 400Hz in our case.

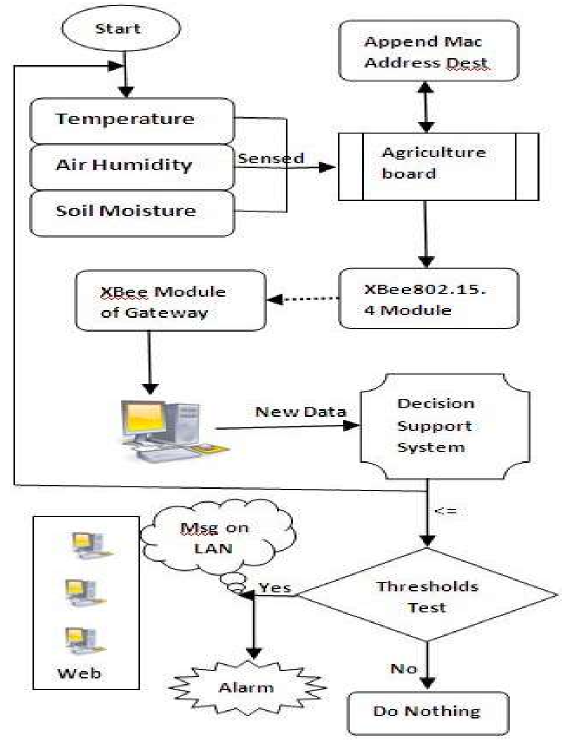

Fig. 5: Block diagram of irrigation management system for container crops

Experimental Evaluations: In order to test and validate the capabilities of the proposed irrigation management system, wasp-mote agriculture sensor boards are deployed at three different locations inside nursery of our institute as shown in Fig.4. The distance between nodes and gateway is adjusted according to their wireless communication ranges. Each board is equipped with temperature, air humidity and soil moisture sensors. Figure 5 presents the design and architecture of the proposed irrigation management system. Sensor boards are deployed inside nursery at different locations. The data is received on the gateway through wireless communication and passed to PC via USB port. Irrigation management system running on PC analyzes this data and checks it for vulnerable conditions. If the sensed parameters reading are below the defined threshold values then a message is send to alarming unit for its activation.

By using the Wasp-mote IDE, the alarming unit is activated by embedding the following simple commands. Wasp-mote IDE is a java based integrated development environment provided by libelium developing corporation for programming their Wasp-mote agriculture boards, gateways, alarming units and other devices but the IDE compiles programs only when one of the Wasp-mote device is connected to the computer through a specified USB port. When a program compiles and run successfully in IDE then it is ready to be laoded and write into specified Wasp-mote module.

- Alarm-unit.begin()
- Alarm-unit.status (Enabled)
- Alarm-unit.delay(300s)
- Alarm-unit.cycle(10)
- Alarm-unit.end()

The first command is used to initialize the alarming unit and just acts like initializing a variable in any programming language. The next step is setting the Alarm-unit.status to ON. For introducing delay in alarming unit, Alarm-unit.delay(time) is used where time represents the delay between different alarms. The code for sending the alarm-unit activation message is implemented in java using socket programming and is presented in two different modules i.e. Server side & Client side module. The Sever side module runs over the PC running irrigation management system and scans the data file for vulnerable conditions i.e. when the parameters values fall below the defined threshold values when soil moisture values are below 400HZ and temperature is above 30C°. The Client side code [29] is running on other PC's connected to the main server and activates its alarming units upon receiving the alarm activation message from Server. In client module, the address of server module is provided in the form of IP address along with port address. The client module enable owners to control their nurseries from a remote location as well. It allows the farmer to check the nursery condition remotely and fulfill plant's needs according to their requirements.

```
class Server
{
void main(String ards[])
   {
ServerSocketss=new ServerSocket(2222);
System.out.println("Server Started");
      Socket q=ss.accept();
System.out.println("Connection Received");
InputStream is = q.getInputStream();
InputStreamReaderisr=new InputStreamReader(is);
BufferedReaderbr=new BufferedReader(isr);
      String d=br.readLine();
System.out.println(d);
System.out.println("/a");
System.out.println("exiting");
     }
   }
```

Server Side Code

```
Class Client
  {
void main(String args[])
       {
       Socket s=new Socket("192.168.155.86",8080);
OutputStreamos=s.getOutputStream();
PrintWriter pw=new PrintWriter(os,true);
pw.println("Received");
pw.flush();
System.out.println("exiting");
       }
   }
```

Client Side Code

Environmental parameters [28] play an important role in the preparation of a more suitable and efficient irrigation schedule. The irrigation schedule of summer is quite different from that of the winter because in winter the water requirements are reduced. Therefore, the proposed system utilizes these parameters for managing irrigation activities in nurseries. The schedule is changed automatically according to the values of temperature, air humidity and soil moisture.

Wasp-mote agriculture board with temperature, humidity and soil moisture sensors are deployed in nursery of our institute as shown in Fig.6 and Fig.7.

Soil moisture sensors are deployed at depth level of 15 cm from ground and 8cm far away from the stem of shrimp plant, rose and aero ceria as shown in Fig.8 and Fig.9. In order to reduce global consumption of power it is switch off after feeding its data to agriculture board. The wasp-mote boards are working in full mode for short period of time and switched to Hibernate mode after sending their data to gateway or other nodes. The data is carefully analyzed by the irrigation management system at the central location and changes the irrigation schedule according to the crops requirements.

Soil moisture is an important parameter for the investigation of plant growth. Fig.10 represents soil moisture values obtained from sensor nodes during August 2012. In our experimental setup, if the soil moisture values are below the threshold value that is 400Hz then the plants are in unsafe state and needs to be watered on urgent bases in order to avoid further damage.

Fig. 6: Wasp-mote agriculture board along with temperature and humidity sensors

Fig. 7: Agriculture boards deployment inside nursery

The yellow region in the Fig.10 represents soil moisture values that are near to safe state but requires attentions of farmer after short time intervals especially in summer when the temperature values are higher than 40-45°C. The green region represents the soil moisture range at which the plants are totally in safe state. If the soil moisture values exceed from 16800Hz then it also represents an alarming state. The abrupt rise in moisture value from 400Hz to 1680Hz is due to irrigation at that particular time interval. The sudden drop in soil moisture value from 1220Hz to 0Hz shows the sensor errors but the proposed system does not take any action regarding these values because soil moisture values change gradually.

Fig. 8: Soil moisture sensor deployment in the shrimp plant container

Fig. 9: Soil moisture sensor deployment in aero ceria plant container

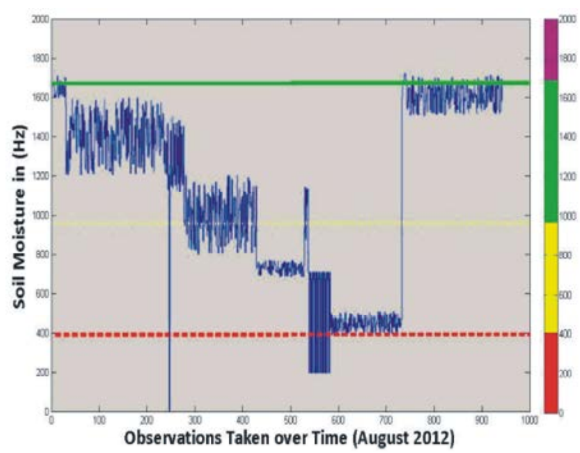

Fig. 10: Change in soil moisture contents over passage of time

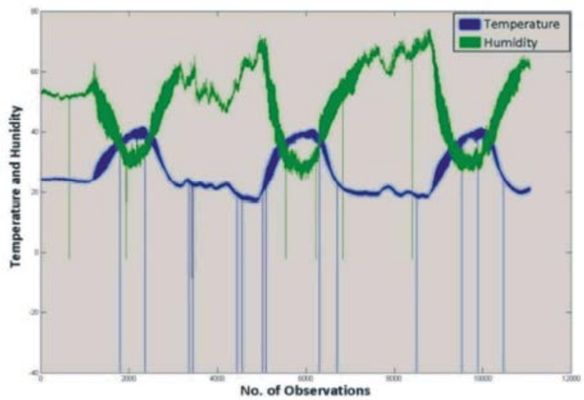

Fig. 11: Temperature and humidity observed in August 2012

Table 1: Irrigation schedule of container crops for dry seasons

Seasons	Open Area	Inside buildings
Summer	2-3 time daily	1-2 time daily
Autumn	Daily or twice special cases	Daily
Winter	After 2-3 days	After4-5 days
Spring	Daily or twice special cases	Daily

Irrigation schedule is affected by changes in temperature and humidity. Fig.11 represents temperature and humidity values obtained from sensor nodes after a defined interval of time that is 30 minutes. Temperature is inversely proportional to humidity as shown in Fig.11. The sudden drop in temperature and humidity values is due to the malfunctioning of sensor nodes such as sensors or communication errors.

In light of our experimental study, irrigation schedules for container grown crops are presented in Table 1. They are kept in an open area as well as inside buildings. The irrigation schedules of crops grown inside buildings are different from the ones grown in open fields. Similarly, it varies from season to season. In summer, the irrigation is performed normally twice a day but in winter it may be delayed up to four to six days for container grown crops. The rain has drastic effects on the irrigation schedules of container crops especially on open field's crops regardless of the seasons. Even in summer, the irrigation schedule can be delayed up to 2-3 day after heavy rain in open fields.

CONCLUSIONS

Water resources are becoming scares in many Asian countries including Pakistan for the last several years. The importance of optimized and efficient irrigation management system development has become the need of time especially the irrigation system that takes decisions over crops soil water contents and environmental parameters. In this paper, irrigation management system for container grown crops is presented. It is deployed inside nursery of our institute for efficient utilization of water. Wasp-mote boards are used to sense temperature, air humidity and soil moisture after a defined interval of time and sent it to a central location via gateway. The irrigation management system separates temperature, air humidity and soil moisture values from each packet and check it against their defined threshold values. If the threshold values are crossed it activates the alarming unit and sent a message via LAN. In second phase of our experiment, the system will be capable of predicting various diseases,sending SMS automatically to the intended users and automatic plotting of data.

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